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I. OVERVIEW

This document describes the "Hatfield Model Version 2.2, Release 1", a flexible tool for estimating the economic costs of providing telephone service to business and residence users throughout the United States. Hatfield Associates, Inc. ("Hatfield Associates" or "HAI") developed this model at the request of AT&T Corp. ("AT&T") and MCI Telecommunications Corporation ("MCI"). This Hatfield Model (called, variously, "the Hatfield Model," "the Model" or "HM") builds upon modeling work that Hatfield Associates performed previously for AT&T and MCI.[1] It uses certain outputs from the Benchmark Cost Model ("BCM") developed by Sprint, NYNEX, MCI and US West ("the Joint Sponsors") to calculate required loop investments.[2] HAI's goal in both these efforts was to model the economic costs of all narrowband local telephone services provided to business and residence customers, including access services provided to interexchange carriers ("IXCs").[3] In addition to computing efficient total network costs, the model computes the economic costs of the individual network elements that are used to provide narrowband telephone services.

The HM develops estimates of economic costs through an engineering model designed to specify the network structure that can provide most efficiently the required telephone services to all customers. As such, it conforms to the Total Service Long Run Incremental Cost ("TSLRIC") pricing rules and standards delineated in Appendix 1 to this document. The HM adopts realistic, but conservative, assumptions concerning the factors influencing prospective network costs to ensure that its economic cost estimates are reasonable and reflective of efficient local exchange carrier ("LEC") construction planning processes.

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1 While most recently, Version 2.1 of the Hatfield Model was presented to the Commission by MCI in, "The Cost of Basic Network Elements: Theory, Modeling and Practice," March 29, 1996, there are several earlier versions. The original Hatfield Model (Version 1.1), was sponsored by MCI in 1994 to gauge the subsidy associated with universal service. This model costed residential access to the first point of switching, local usage, touch tone, white pages listings and access to 911, operator and directory assistance service. The model assumed a scorched earth approach, no direct interoffice trunking and homogeneous population density zones. This model evolved in two directions. Version 2.0, which costed all local services, was introduced in a Maryland price cap proceeding in late 1995. Version 1.2 was also introduced in late 1995 in Pennsylvania to gauge universal service subsidy needs. In Version 1.2, the scorched earth approach was replaced with a scorched node approach using outputs from the Benchmark Cost Model ("BCM") to size loop plant requirements.

2 Users must obtain the BCM from the Joint Spnsors in order to use it as an input to the HM.

3 The specific network that the model costs is one that is capable of carrying all switched voice/narrowband telephone services that are offered within an exchange area. To the extent that the network elements used to provide these services are also capable of providing other services (e.g., ISDN, special access, or private line services), their costs are estimated as well.

The Hatfield Model is flexible. It uses public information made available from the Federal Communications Commission ("the Commission") and industry publications for its basic input data. In addition, the HM will easily accept substitute proprietary or company-specific information. Users may apply the HM to any LEC or geographic area, because the necessary inputs are publicly available. The HM's table driven structure and the nature of its output reports, facilitate a variety of flexible uses of the model.

The sections that follow provide a more detailed discussion of the HM's structure, processes and operations. In particular, this document describes only the portions of the model that address the cost of the local network and its individual elements. This document does not address Universal Service or subsidy issues. Section II describes the HM and its potential applications. Section III documents in detail the Model's inputs and processes used to determine the most efficient network structure that will serve the required level of customer demand and describes the derivation of unbundled network element TSLRICs from this optimized network model Section IV displays some numeric results derived by the Model.

II. GENERAL DESCRIPTION OF THE HATFIELD MODEL AND ITS POTENTIAL APPLICATIONS

The Hatfield Model develops estimates of the economic costs (TSLRIC) of providing local telephone services by determining the specifications of a local network, using most efficient practices and best forward-looking technologies, to meet the total demand for local narrowband telephone services. By doing this, the model simulates the construction and operations decision-making of an efficient local service provider that must create and operate a new network to meet current and reasonably forecasted demand levels for narrowband telephone services. In simulating the construction of these hypothetical networks, the model incorporates realistic assumptions concerning the LECs' ability to adopt and implement efficient, cost minimizing production techniques.

A. EFFICIENT FORWARD-LOOKING PRODUCTION

As required by TSLRIC study principles, the Hatfield Model assumes that the LEC acts as an efficient, cost minimizing producer of basic telephone services and makes rational, forward-looking investment decisions over a long-run planning horizon. The HM assumes that all plant related investments and expenses are variable. The Model optimizes these investments and expenses by configuring the least-cost network required to serve existing demand, subject to constraints reflecting a conservative assessment of the LECs' ability to change some of the underlying physical characteristics of their embedded networks.

B. ADOPTION OF APPROPRIATE TECHNOLOGIES

The technologies considered in the Model are forward-looking. As such, they are those an efficient LEC would adopt if it were to begin today to rebuild its telephone service network from the bottom up. For outside plant calculations, a technology mix composed of a digital loop carrier, copper distribution and feeder plant and optical fiber feeder plant is assumed. The HM does not consider hybrid coaxial cable because there is a continuing controversy over whether it is the least-cost technology for providing narrowband service. Wireless technologies are also excluded because, though promising, they are not yet a proven or generally available primary local service alternative that is a quality or economic substitute for wireline local service. The particular architecture chosen for a serving area reflects an assessment of the least-cost method of providing telephone service to a serving area. For example, the feeder and distribution plant sizing algorithms choose the minimum quantity and size of cables to meet total demand and reflect the tapering of feeder cable segments as routes extend away from the wire center.

Switching cost calculations in the model use digital switching and current demand characteristics. Switching capacities are consistent with those of present generation digital switches, such as AT&T's 5ESS® and the Northern Telecom DMS-100®. The HM assumes that the LECs have deployed fully SS7 signaling capabilities throughout the local exchange network.

C. FIXED WIRE CENTER LOCATIONS

The HM is a "scorched node" study because it uses the Benchmark Cost Model ("BCM") loop investment assumption that treats the LECs' current wire center locations as "fixed" nodes in a reconstructed local network. Because this approach does not allow for relocating wire centers to minimize the total cost of providing telephone service, this assumption creates an upward bias in the model's estimates of local service costs.

D. EXISTING GEOGRAPHY AND CHARACTER OF DEMAND

The Hatfield Model considers only those investments required to support the efficient provision of traditional narrowband telephone services. The Model does not cost out speculative investments to accommodate provision of broadband services or potential demand stimulation from possible enhanced service applications. Nor does the Model inflate demand estimates to account for overbuilt official networks.

The HM incorporates demand for both business and residence service, including second residence lines, through adjustments to BCM line counts of households by Census Block Group ("CBG"). By engineering the network so that current demand only partially fills its capacity, the Model accommodates growth in the demand for such services, including all basic network functions underlying local telephone service. The HM sets these network fill factors at levels an efficient local service provider would expect to achieve. The HM varies network fill factors by population density zone, an assumption that accommodates cost differences resulting from differences in rates of population growth across density zones. The HM does not use current LEC network fill factors because such factors reflect LEC inefficiencies (induced for example, by overbuilding to accommodate plans to enter new markets).

The Hatfield Model meets additional design criteria by providing a flexible, generic structure for estimating company-specific TSLRICs for basic telephone services and for unbundled network elements that the LEC may supply to its carrier customers. The specific inputs used to drive the present model are uniformly available for all companies and study areas and can be modified easily to reflect any other forward-looking, company-specific or proprietary information a user may wish to use. Required inputs derived from the BCM and underlying demand measures are now available for all study areas. Residence and business line counts and information concerning current period expenses and costs, are directly available for all companies that file ARMIS reports. Though the exact prices LECs paid for particular capital goods are generally proprietary, the HM obtains information concerning prevailing prices for outside plant and switching facilities through public industry sources. Finally, the best practices and economic principles on which the model rests transcend company boundaries.

E. POTENTIAL APPLICATIONS OF THE HATFIELD MODEL

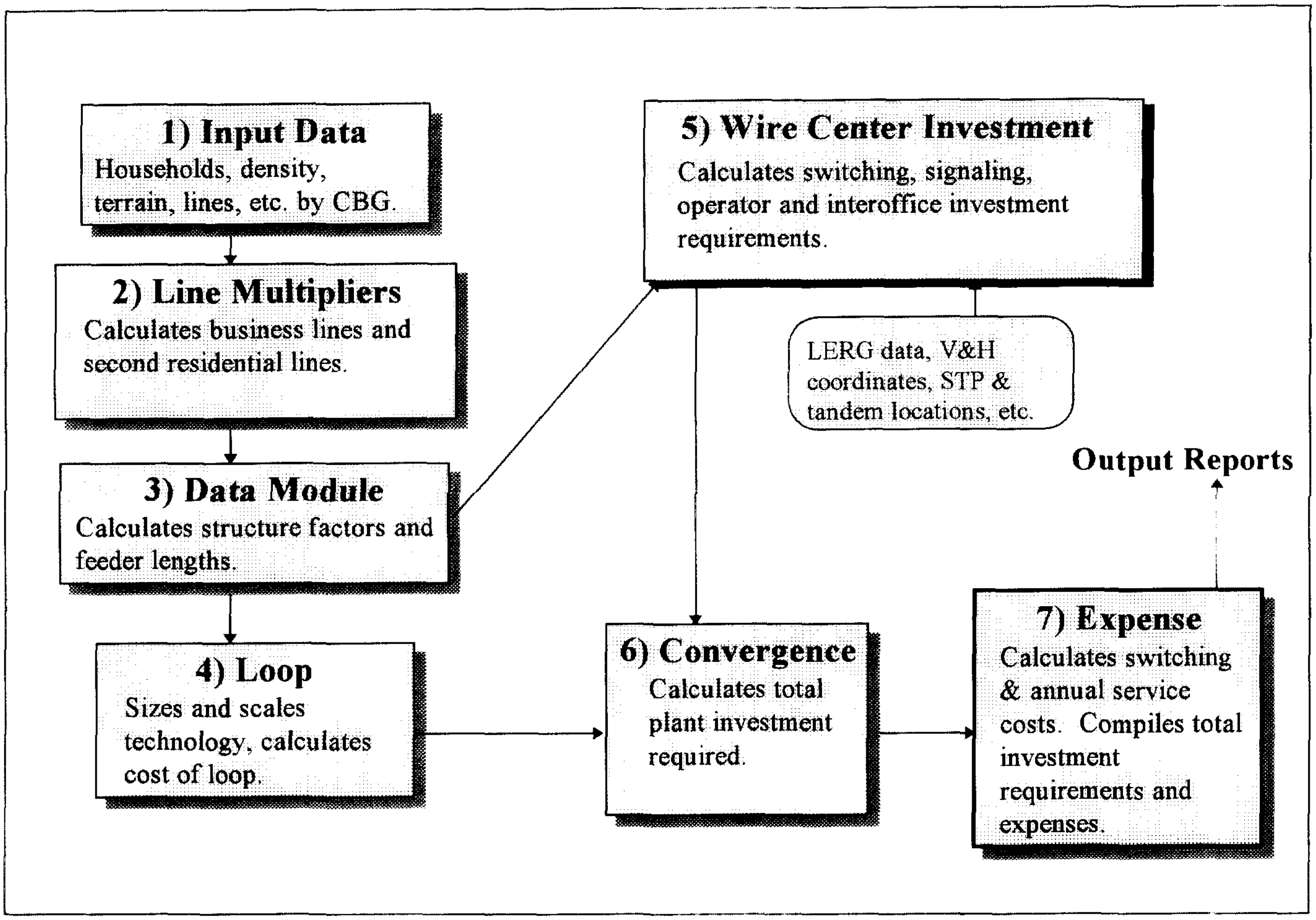
The Hatfield Model can be used for a variety of applications for which TSLRIC estimates are required. The Model's primary application is to develop estimates of the TSLRIC and local access of unbundled network elements and interconnection services that compose local exchange service. The Model may also be used to assess economic subsidy requirements by identifying those areas in which the TSLRIC of basic local service exceeds the tariffed rate for that service and by quantifying any resultant economic shortfall.

III. STRUCTURE OF THE MODEL

A. OVERVIEW OF MODEL ORGANIZATION

The Hatfield Model contains seven functional modules. It uses output from three components of the BCM to determine loop investment. It couples this with its own modules to produce the wire center and outside plan investments necessary to provide switching, signaling, operator and trunking functions -- along with their required support expenses. Figure 1 shows the relationships among these modules. An overview of each component module follows

Figure 1 Hatfield Model Organization Flow Chart



1. Input Data

There are two categories of raw data upon which the Hatfield model relies. They are CBGs (based on Census Bureau statistics) and wire center specific data (based on Local Exchange Routing Guide ("LERG") data) [4]

The specific CBG data used by the model are: 1) number of households; 2) CBG land area in square miles; 3) position relative to nearest wire center; and 4) local geological factors including rock depth, rock hardness, water table and surface texture. The current locations of individual wire centers and their particular technical specifications (as reported in the LERG) are also entered as variables into the cost model.

[4] "Local Exchange Routing Guide," Bellcore 1995 Users must obtain these data from Bellcore.

2. Line Multiplier

Since the model calculates all network costs on a per line basis, it must first calculate the number of second residential, business, public and special access lines within each CBG. Because the U.S. Census Bureau collects only household data and the FCC's Statistics of Communication Common Carrier or ARMIS 43-08 reports line data aggregated across all services, the model must apply multiplier factors to account for these additional access lines

This calculation is based upon two assumptions: 1) multipliers must be greater than zero; and 2) increases in population density result in higher ratios of residence second lines and business lines to the number of households. Thus, the outputs of the Line Multiplier Module are estimates of total lines in a CBG and a table of line totals and line multipliers for six different population density ranges. Population density is measured by households per square mile and is broken into six categories: 0-5, 5-200, 200-650, 650-850, 850-2,550 and greater than 2,550 households per square mile. Labeling for these density zones is given in Table 1.

Table 1 Density Zone Households Per Square Mile

Density Zone	Households/Sq. Mile
1	0-5
2	5-200
3	200-650
4	650-850
5	850-2550
6	> 2550

3. Data Module

The Data Module calculates so-called "structure factors" for distribution and feeder cable plant that take into account the degree of difficulty associated with placing and installing cable under varying terrain and population density conditions. The module uses CBG data and line multipliers to first determine the quantity and type of outside plant required based on spatial geometry, density and distance of the CBG from the wire center. The HM also incorporates the particular geologic characteristics of each CBG (such as rock hardness, soil type, surface texture and water table depth) into its structure factors.

4. Loop Module

The Loop Module uses the structure factors calculated in the Data Module and estimates cable investments per unit length to determine the total required loop investment per CBG. To determine the full network loop investment, the module selects copper feeder technology for CBGs with loops less than 12,000 feet and selects fiber feeder technology for CBGs with loops longer than 12,000 feet. The module then determines the size of copper or fiber cable required to serve each CBG, given prescribed fill levels and population density. Once the module has determined the required type and size cable, the Loop Module calculates the necessary total distribution, feeder and supporting structure investment using the Data Module's structure factors.

5. Wire Center Module

The Wire Center Module is a Hatfield extension to the BCM. It calculates wire center and interoffice facilities investments on a per line basis. This module quantifies investments associated with end office switches, trunks, signaling links, wire centers, signal transfer points ("STPs"), tandems (including operator tandems) and operator positions. The module uses the CBG household and line multipliers and the location of wire centers as detailed in the LERG to determine required switching capacities and interoffice investments.

In keeping with TSLRIC principles, the model determines network capacity sufficient to serve all demand in its service area. The HM derives its switch investment estimates by using both typical per-line prices paid for by Bell Operating Companies, GTE and other independents,[5] and from Table 2.10 of the FCC's Statistics of Communications Common Carriers, which provides the average number of access lines served by a LEC switch.

6. Convergence Module

The Convergence Module combines output of the Loop Module (loop installation, material and structural investments) with the Wire Center Module (per-line wire center and interoffice investments). The convergence module reports by density ranges the number of lines by type, number of households and investment in categories such as distribution, feeder, switching, tandems, trunks, etc.

7. Expense Module

The Expense Module uses output from the Convergence Module to determine efficient annual capital carrying costs for the investments needed to build up a local telecommunications network that reflects TSLRIC principles. This module uses investment, revenue and expense data that are available from LEC annual ARMIS reports and depreciation factors by plant category and it is capable of using individual LEC's levels of financial leverage and cost of debt and equity.

The Expense Module also calculates support expenses based on certain ratios between these expense items and the investments they support.

[5] See *U.S. Central Office Equipment Market -- 1994*. McGraw-Hill.

B. INPUT DATA FILE

1. Overview

The purpose of the data input or "Input Data" file is to incorporate into the HM objective publicly reported and company neutral topographical data and demographic statistics for use throughout the model. These data are derived from U.S. Census Bureau STF3 data, NECA Tariff 4 CLLI data,[6] and USGS Satellite Survey Data.[7] In addition, the Joint Sponsors used "ARC INFO" and "Map Info" software to translate the government data into parameters that match the BCMs input needs.[8]

2. Description of Inputs and Assumptions

In addition to three cells designated to identify a specific serving area (wire center or CLLI, company and CBG number), there are a total of eleven elements that are collected in the BCM Input Data File. They are:

Measurements of Distance to Centroid, Quadrant, Omega and Alpha[9] -- These variables locate the CBG with respect to the wire center. There are four quadrants surrounding a wire center. The Alpha and Omega values are angles used to determine feeder and distribution lengths. Omega is the angle that determines in which quadrant of the serving area the CBG falls. Alpha is the angle between the line directly linking the wire center and the center of the CBG and the link followed by the main feeder route serving the CBGs quadrant. The Data Module will use these measurements to determine the feeder, sub-feeder and distribution lengths. The Loop Module uses these values to compute material and placement investment and to share feeder investment among the several CBGs served by a common feeder route. The Joint Sponsors used "ARC INFO" and other software to map CBGs to the nearest wire center and to determine these geometric parameters.[10]

Geographic Information -- As part of the Input Data File, the BCM uses total CBG household counts and areas obtained from census data. The HM uses these values to calculate population density. The Data Module identifies the six zones of population density.

Terrain Variables -- The model incorporates terrain variables extracted from USGS Satellite Survey data. These include water table depth, depth to bedrock, bedrock hardness and surface texture. In the Data Module, these variables help to determine additional cost

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6 Common Language® Location Identifier. Common Language® is a trademark of Bell Communications Research.

7 CC Docket 80-286. Joint Sponsors, December 1, 1995 filing, at IV-7, IV-8.

8 CC Docket 80-286. Joint Sponsors, December 1 1995 filing, at IV-7, IV-8.

9 CC Docket 80-286. Joint Sponsors, December 1 1995 filing, at IV-10 through IV-12.

10 CC Docket 80-286. Joint Sponsors, December 1 1995 filing, at IV-10 through IV-12.

factors for installing different types of cable. Some of the variables are quantitative (Rock Depth and Water Table Depth), while others are qualitative (Rock Hardness and Surface Texture). The Data Module assigns numeric values to this qualitative data.

Table 2 below presents the minimum and maximum values for these data from the first 200 CBGs reported for Colorado to illustrate the range and type of the geological variables.

Table 2 Variable from the BCM Input Data File and High and Low Values Surveyed from First 200 CBGs in Colorado

Variable	Column	Data Type	High	Low
Centroid Distance	G	Quantitative	104472.61	143.59
Total Households	H	Quantitative	1215.00	29.00
Area	I	Quantitative	569.78	0.06
Density	J	Quantitative	9098.91	0.09
Rock Depth	K	Quantitative	60.00	11.20
Rock Hardness	L	Textual	HARD	SOFT
Surface Texture	M	Textual	*	*
Water Table Depth	N	Quantitative	6.00	4.11
*There are nearly 200 different surface texture types assigned values of 1 or 0.				

3. Description of Module Outputs and Connection to Next Module

The BCM Input Data File, with the line counts substituted for household counts, serves as the input file for the BCM Data Module. In addition, it functions as a repository of essential data that all the subsequent modules draw upon to calculate network investments, including the Line Multiplier Module, the BCM Loop Module and Wire Center Investment Module.

C. LINE MULTIPLIER MODULE

1. Overview

A key feature of the Hatfield Model is that it takes into account all significant sources of demand for loop facilities, including residence, business, public and special access lines, rather than focusing strictly on primary residential access line demand as the BCM does. The Line Multiplier Module makes this extension to the BCM. As shown in Figure 1, this module calculates total access line counts for each CBG and provides these data to the BCM's Data Module.

The HM incorporates all access line demand to account for any potential the scale or scope economies associated with the provision of both residence and non-residence services. As a result, the Hatfield Model can provide reasonable estimates of business loop investment.

2. Description of Inputs and Assumptions

The Line Multiplier module uses access line demand data from the Operating Data Reports, ARMIS 43-08, submitted to the FCC's Common Carrier Bureau on an annual basis by all Tier 1 LECs.[11] The HM developers obtained these data from Table III ("Access Lines in Service") of those carriers' 1994 ARMIS 43-08 reports and entered it into the model without any adjustments. The HM includes the following company-wide data for each of the LECs[12]

- Residential access lines, including analog and digital. These totals include all residential switched access lines, including flat rate (1FR) and measured rate (1MR) service.[13]
- Business access lines, including analog single line, analog multiline and digital. These totals include flat rate business (1MB) and measured rate business (1MR) single lines, PBX trunks. Centrex lines, hotel/motel LD trunks and multi-line semi-public lines.[14]
- Special access lines, including analog and remote digital. These totals include dedicated lines connecting end users' premises to an interexchange carrier point of presence, but do not include intraLATA private lines.[15]
- Public access lines, that is, lines associated with coin (public and semi-public) payphones, excluding customer owned pay telephones ("COPT").[16]

As explained below, the module's algorithms map the data to individual CBGs. This requires certain inputs from the Data Module, namely a listing of each CBG (identified by CLLI code of the wire center, company name and CBG code) and its associated household count This module draws these parameters from the Input Data file.

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11 See Reporting Requirements for Certain Class A and Tier 1 Telephone Companies (Parts 31, 43, 67 and 69 of the FCC's Rules), CC Docket No. 86-182, 2 FCC Rcd 5770 (1987) (ARMIS Order), modified on recon., 3 FCC Rcd, 6375 (1988). Tier 1 LECs are those with more than $100 million in annual revenues from regulated services and includes over 50 carriers.

12 These LECs include the seven RBOCs, GTE California and GTE Texas.

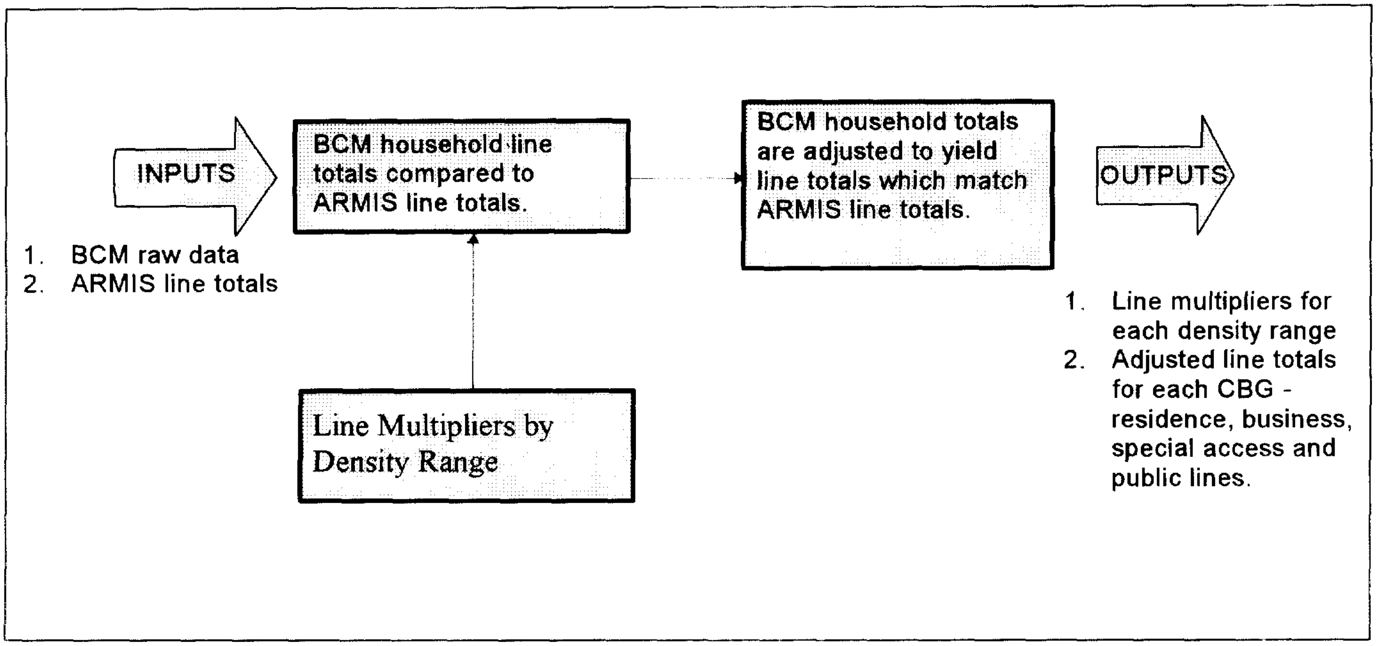
13 Revision of ARMIS USOA Report (FCC Report 43-02) for Tier 1 Telephone Companies and Annual Report Form M, AAD 92-46, DA 92-1405, released October 16, 1992, Appendix C, at FCC Report 43-08 - Report Definition for Table S-3 page 2.

14 *Id.* at FCC Report 43-08 - Report Definition for Table S-3, pages 1-2.

15 *Id.* at FCC Report 43-08 - Report Definition for Table S-3, pages 2-3

16 *Id.* at FCC Report 43-08 - Report Definition for Table S-3, page 2.

Figure 2 Line Multiplier



3. Explanation of Key Algorithms

The Hatfield Model, like the BCM, uses the CBG as a basic unit of analysis. Therefore, to take into account sources of access line demand other than residence service, the Model must estimate the demand for such services; e.g., business, special access and public access lines, within each CBG. This data is not provided publicly by the LECs, although they do possess service-specific demand data at a wire center level. Rather, the LECs allege that these data are proprietary (e.g., for competitive Centrex services). Thus they are not currently available for incorporation into the HM.[17]

As an alternative, the Line Multiplier Module uses a consistent method to translate the ARMIS access line data that LECs report on a territory-wide basis into service-specific access line counts on a CBG basis. The module performs this translation separately for each service category (residence, business, special access and public access line). In each case, the total number of lines reported for the service category are assigned to specific CBG based upon explicit, user-modifiable assumptions regarding how demand for the service varies by Density Zone.

[17] Curiously, some RBOCs, notably the Southwestern Bell companies, formerly published this information for use by their interexchange carrier customers, but the practice has apparently been discontinued. See SWB, *Interexchange Customer Information Handbook*, Volume IV (End Office Profile), 1987

The first step of the Line Multiplier Module's algorithms is to assign a primary residence access line to each household identified in the CBG data provided by the Data Module.[18] The remaining residence access lines (i.e., the total ARMIS residence line count for the given LEC minus the household count), as well as the lines associated with each of the other service categories, are then assigned to individual CBGs based on a set of "line multiplier" factors (see Figure 2). Table 3 below illustrates representative line multiplier values.

Table 3 Illustrative Line Multipliers

Density Zone	Total Multiplier	Two-Line Households	Business Line	Special Access	Public Access
1	1.045	0.00	0.02	0.025	0.000
2	1.118	0.02	0.05	0.038	0.010
3	1.296	0.04	0.20	0.045	0.011
4	1.479	0.06	0.35	0.055	0.014
5	1.622	0.10	0.44	0.063	0.019
6	2.106	0.30	0.70	0.080	0.026

Specifically, the Line Multiplier Module uses an iterative process to estimate the demand within each CBG for lines associated with each of the four service categories. In the initial calculation, the HM assigns each CBG a line count for each service category (e.g., business access lines) by multiplying the household totals in each CBG by the initial user-specified line multipliers. For example, if the household count for a particular CBG in Density Zone 3 is 100 and the Additional Lines multiplier is 0.04 (see Table 3), then the HM assigns 4 = 100 x 0.04 additional lines to that CBG. The module then compares total line count for all CBGs to the service category's line count reported in ARMIS. If the totals within a service category fail to reconcile within ± 0.5%, then the module adjusts the multiplier factors upward or downward and the totals are recalculated. This process continues until the totals for each service category are within a ± 0.5% tolerance range.

The module contains an Iteration Macro to automatically adjust the line multipliers; alternatively, the module also allows for a manual adjustment. In either case, the module applies the same basic constraints, namely that the multipliers must be non-negative and increase monotonically with increasing population density. These rules reflect a presumption that sparsely populated areas will tend to have fewer business and second residential lines in proportion to household count than will more densely populated areas. Although specific CBGs may exhibit exceptions from this trend, at higher levels of aggregation (e.g., the wire center or LATA level), the mix of services will progressively approach the total company mix reported in the ARMIS data.

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18 Some additional lines are added to reflect growth in primary residence access line demand due to net gains in households that occurred between the 1990 time frame of CBG household data collected by the U.S. Census and the 1994 time frame of the FCC ARMIS data.

The line multipliers are user-specified inputs. Therefore, users can adjust them to reflect LEC-supplied data on service penetration levels by density zone (if such data becomes available), tested for sensitivity effects, or otherwise modified at the discretion of the model user.

4. The Modeling of Business Loop Lengths

LECs have asserted that business lines typically have shorter loop lengths than residence lines and therefore should have lower average loop investment costs. Although the BCM algorithms used to determine loop distance make no explicit distinction between residence and business (and other non-residence) loops, the Line Multiplier Module allows for such distinctions. By using business line multipliers that increase the proportion of business lines assigned to the higher density zones, the average loop investment for business lines will reflect both the shorter feeder distances required to serve CBGs in more densely populated areas and the shorter distribution distances that characterize the more compact CBGs found in denser areas.

In the rural zones where CBGs encompass larger geographic areas, the BCM's assumption of uniformly distributed customer locations may overstate somewhat the distribution lengths and associated investment costs for business lines, especially because business locations are likely concentrated nearer the center of the CBG. However, the BCM independently calculates feeder and sub-feeder distances; hence, any possible overstatement of distribution lengths for business lines will not affect these calculations. Accordingly, the sizing of feeder cables and associated support structure will also be unaffected by any overstatement of business lines' distribution distances, so the Model will capture accurately any scale or scope economies engendered by carriers' provision of multiple access line services.

5. Description of Module Outputs and Connection to Next Module

The primary output from the Line Multiplier Module is the Input Data File modified with additional residential, business, special access and public lines. Both the Data Module and the Wire Center Module use these data.

D. DATA MODULE

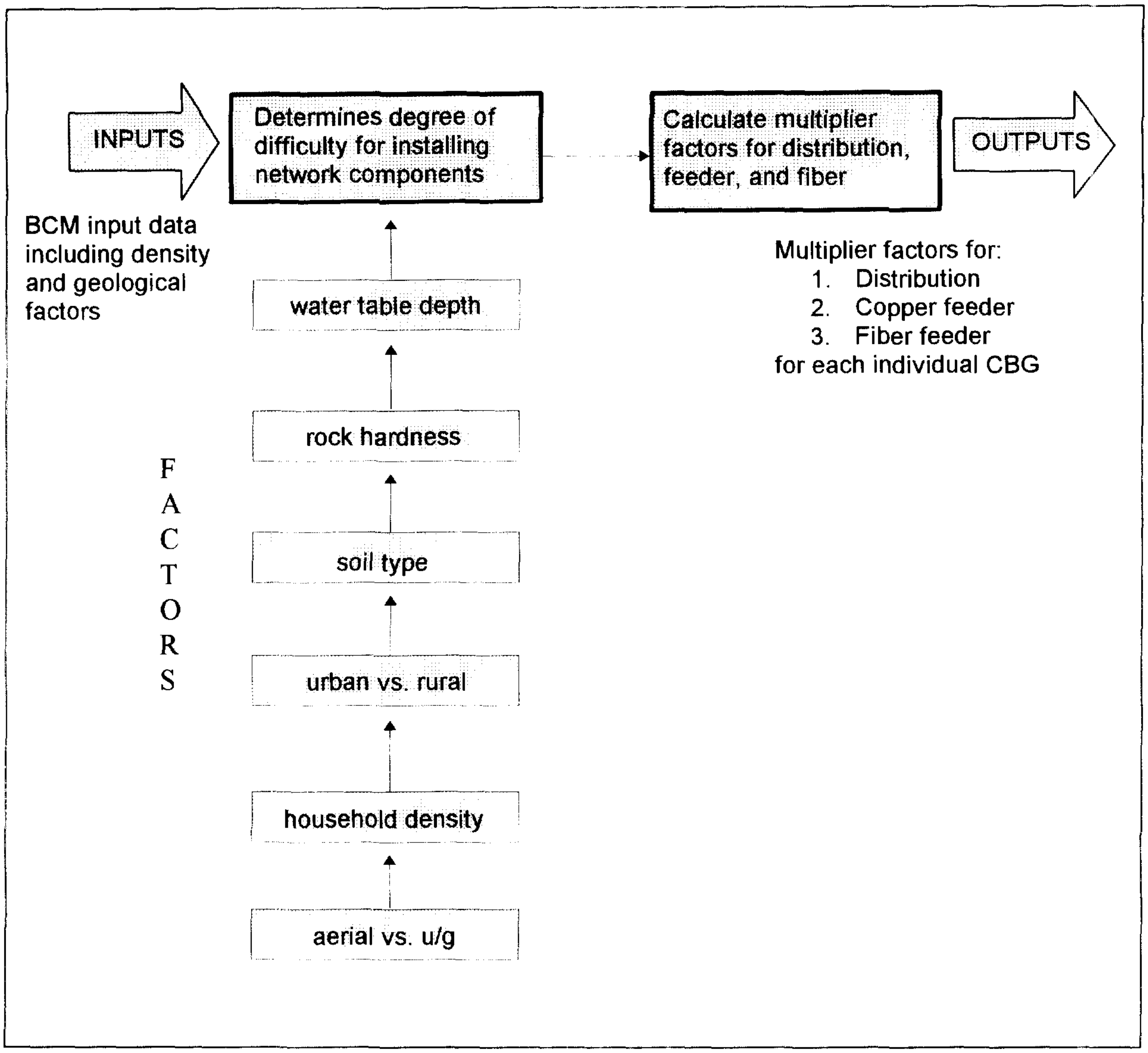
1. Overview

The Data Module is the first module of the BCM. The input for the Data Module is the BCM Input Data File. The results from the Data Module, in turn, are the input to the Loop Module. The Hatfield Model inserts the Line Multiplier Module before the two, but its output does not affect the operation of the Data Module. The BCM developers have designed the Data Module to accomplish two functions:

- Calculate lengths for the feeder, sub-feeder (if required) and distribution portions of the loop.
- Determine the appropriate cost structure multipliers to each of the loop segments (feeder, sub-feeder and distribution) to reflect the costs of conduits, innerduct, poles, etc., as well as the capitalized costs of cable placement.

The HM generally uses the structure cost values which the Data Module produces, with one exception. Because the BCM appears to understate the distribution structure costs in sparsely populated areas the HM selectively increases this value in certain low density CBGs.

Figure 3 Data Module



2. Description of Inputs and Assumptions

The Data Module bases its loop length calculations on a number of important assumptions adopted by the BCM's developers. They include the following:

- Feeder cable extends from the wire center to the edge of the CBG.
- There are four main feeder routes that leave each wire center with sub-feeder routes placed at 90 degree angles from the main feeder routes.
- Households are distributed evenly throughout a CBG.
- Distribution cables must extend from the edge of the CBG to each customer premises.

- Four equal-length distribution legs are used to serve each CBG. The size of the CBG determines the length of each leg.

3. Explanation of Key Algorithms

The Data Module calculates loop distances and structure costs. The following describes these key loop calculations.

a) Calculating Segment Lengths

To calculate the lengths of feeder segments in the network, the BCM employs trigonometric functions to create a right triangle -- one side being the airline distance from wire center to the center of the CBG, a second side being the feeder route and the final side the sub-feeder. The Joint Sponsors describe this in their December 1, 1995, filing.[19]

Main Feeder Distance -- The BCM Input Data File gives the CBG centroid distance and the appropriate angle. The Data Module calculates the main feeder distance.

Sub-feeder Distance -- The BCM assumes that all CBGs are square and calculates the length of one side of the CBG as the square root of the CBG area. The BCM then determines if sub-feeder is necessary. If the sub-feeder length is less than half of the CBG side, a portion of the CBG overlaps the main feeder and the model sets the sub-feeder length at zero.[20]

Distribution Distance -- The BCM uses other geometric relationships to calculate distribution distances. The distribution distance is the average distance between a household and the center of the CBG. Implicit in this calculation are assumptions that: 1) households are uniformly distributed in the CBG, 2) the CBGs are square, 3) the feeder plant ends at the edge of the CBG and 4) the average distribution plant length equals to the sum of the average horizontal distance of distribution plant and the average vertical distance of distribution plant. The module calculates the average distribution distance within one CBG as 0.75 of the length of one side of the CBG.[21] Because populations tend to cluster in towns and subdivisions, the BCM assumption of uniform population distribution tends to overstate distribution distance and thus the required loop investment.

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19 FCC 80-286, Joint Sponsors, December 1, 1995 filing, Attachment 4 at IV-10-12.

20 The main feeder distance will be overstated whenever the CBG boundary crosses the Main Feeder route, since the algorithm does not subtract the portion of the calculated Main Feeder that extends beyond the intersection of the CBG, whereas the Distribution calculation assumes that the Main Feeder ends at the edge of the CBG. Because the larger CBGs found in low density areas are more likely to cross the Main Feeder route, loop costs will tend to be somewhat overstated in low density zones.

21 FCC 80-286, Joint Sponsors, December 1, 1995 filing, Attachment 4 at IV-14.

b) Structure Multipliers

A variety of demographic and geological factors affect the choice of loop plant, as well as the costs of initial placement. These include the population density, the nature of the soil and the prevailing water table depth. The Data Module calculates the effects of these terrain variables as "structure multipliers." These multipliers also incorporate the material costs of poles, conduit, inner ducts and other structure. The Data Module calculates separate structure factors for placing copper distribution cable, copper feeder, and fiber feeder.

The formulas associated with these cost multipliers use a set of look-up tables. There are a total of 54 of these weighted cost factors which range from a magnitude of 0.233 (the multiplier for distribution plant in rural areas with the lowest household density and with "normal" surface texture) to 11.5456 (the multiplier for fiber plant in urban areas with the greatest household density and the hardest surface texture). To derive the weighted cost factor table, the Data Module matches all the terrain variables to a cost for using different types of cable and multiplies them together (see Figure 3 for a presentation of the logic used to generate these cost structure factors). The module derives these weighted cost factors from 24 "unweighted" cost multipliers. Four tables are generated: Urban Copper Cable, Rural Copper Cable, Urban Fiber and Rural Fiber.

Table 4 shows the cost multipliers for copper feeder and copper distribution in density zones 5 and 6 The BCM developers define these as "urban" density zones.

Table 4 Urban Copper Cable Cost Multiplier

Structure	Underground Cost Factor	Aerial Cost Factor
Rock "Hard"	1.53	0.69
Rock "Soft	1.22	0.48
Rock Normal	1.11	0.48

Table 5 shows the corresponding multipliers in the four lowest density zones.

Table 5 Rural Copper Cable Cost Multiplier

Structure	Underground Cost Factor	Aerial Cost Factor
Rock "Hard"	0.66	0.80
Rock "Soft	0.35	0.54
Rock Normal	0.21	0.44

Table 6 contains the multipliers for fiber feeder in density zones 5 and 6 and Table 7 shows the fiber multipliers for the rural zones 1 through 4

Table 6 Urban Fiber Cable Cost Multiplier

Structure	Underground Cost Factor	Aerial Cost Factor
Rock "Hard"	9.02	3.50
Rock "Soft	7.22	2.50
Rock Normal	6.56	2.50

Table 7 Rural Fiber Cable Cost Multiplier

Structure	Underground Cost Factor	Aerial Cost Factor
Rock "Hard"	3.00	4.25
Rock "Soft	1.45	2.90
Rock Normal	1.02	2.30

The module then weights the values in these tables by the underground/aerial ratios for distribution cable (always copper), copper feeder and fiber feeder. The "mix" of these architectures varies by density zone (see below).

Table 8 Distribution (Copper) UG/Aerial Mix

Density	UG %	Aerial %
1	90	10
2	80	20
3	70	30
4	65	35
5	60	40
6	50	50

Table 9 Copper Feeder UG/Aerial Mix

Density	UG %	Aerial %
1	60	40
2	65	35
3	70	30
4	80	20
5	90	10
6	100	0

Table 10 Fiber Feeder UG/Aerial Mix

Density	UG %	Aerial %
1	60	40
2	65	35
3	70	30
4	80	20
5	90	10
6	100	0

The formulas in the Data Module are relatively simple references to the look-up tables. However, the module does make several preliminary calculations.

A general description of several of the more important of these preliminary calculations follows.

Density -- In order to determine cost factors, the Data Module places CBGs into one of six density zones. The HM designates the top two density zones as "urban" within which the model applies a 1.28 cost multiplier to account for the higher costs associated with placing plant in urban areas. In addition, density zones determine the aerial/underground mix of copper and fiber cable.

Surface Texture Indicators -- The original data from the USGS Satellite Survey data is qualitative in nature (e.g., clay loam). The surface texture definitions lead to a binary indicator in the Data Module: a "1" indicates an additional cost and a "0" indicates no additional cost.

Copper Depth Condition -- The Data Module assumes a value of 24 inches for the normal placement depth for buried/underground copper cable. The Data Module matches this assumption with the original input variables of rock depth, rock hardness and surface texture for all CBGs. The BCM calculates values from 1 to 3 based on the expense of placing copper cable in that specific CBG. A value of "1" is the most expensive.

Fiber Depth Condition -- Similar to copper depth, fiber depth determines the costs associated with placing fiber given the specific terrain characteristics of each CBG. The BCM uses a value of 36 inches for the normal placement depth of buried/underground fiber. This function also produces a value from 1 to 3. A value of "1" is the most expensive.

Ultimately, the "Cost Factor Table" (which incorporates all geographic factors, except for the water table depth) drives Data Module outputs. If the water table depth is less than 3 feet, the value that the model derives from the cost factor table is multiplied by 1.3.

Tables 11 and 12 are the final lookup tables for loop distribution and feeder structure factors.

Table 11 Cost Factor Table for Distribution

Urban/Rural	Density Zone	Surface Category	Weighted Cost Factor
Urban	6	Rock H Rock S Normal	1.42 1.09 1.02
Urban	5	Rock H Rock S Normal	1.19 0.92 0.86
Rural	4	Rock H Rock S Normal	0.71 0.42 0.29
Rural	3	Rock H Rock S Normal	0.70 0.41 0.28
Rural	2	Rock H Rock S Normal	0.69 0.39 0.26
Rural	1	Rock H Rock S Normal	0.67 0.37 0.23

Table 12 Cost Factor Table For Feeder

Cable	Area	Density Zone	Terrain	Factor
Copper	Urban	6	Rock H Rock S Normal	1.96 1.56 1.42
Copper	Urban	5	Rock H Rock S Normal	1.45 1.15 1.05
Cooper	Rural	4	Rock H Rock S Normal	0.69 0.39 0.26
Copper	Rural	3	Rock H Rock S Normal	0.70 0.41 0.28
Copper	Rural	2	Rock H Rock S Normal	0.71 0.42 0.29
Copper	Rural	1	Rock H Rock S Normal	0.72 0.43 0.30
Fiber	Urban	6	Rock H Rock S Normal	11.55 9.24 8.40
Fiber	Urban	5	Rock H Rock S Normal	8.47 6.75 6.15
Fiber	Rural	4	Rock H Rock S Normal	3.25 1.74 1.28
Fiber	Rural	3	Rock H Rock S Normal	3.38 1.89 1.40
Fiber	Rural	2	Rock H Rock S Normal	3.44 1.96 1.47
Fiber	Rural	1	Rock H Rock S Normal	3.50 2.03 1.53

4. Outputs

The Data Module creates outputs that are used by the Loop Module. The following describes these outputs and indicates whether it is used in calculating the network cable lengths (for feeder, sub-feeder and distribution lengths) or terrain effects (cost multipliers). Other data transferred from the Data Module to the Loop Module are company name, wire center identification (CLLI code), block group number, quadrant, total households and density.

Table 13 New Data for Loop Module

Category	Column	Function
B	E	Cable lengths
A Feeder Portion	F	Cable lengths
Distribution Distance	G	Cable lengths
Distribution Cable Multiplier	J	Terrain effects
Copper Feeder Cable Multiplier	K	Terrain effects
Fiber Multiplier	L	Terrain effects
B Segment distance	M	Cable lengths

E. LOOP MODULE

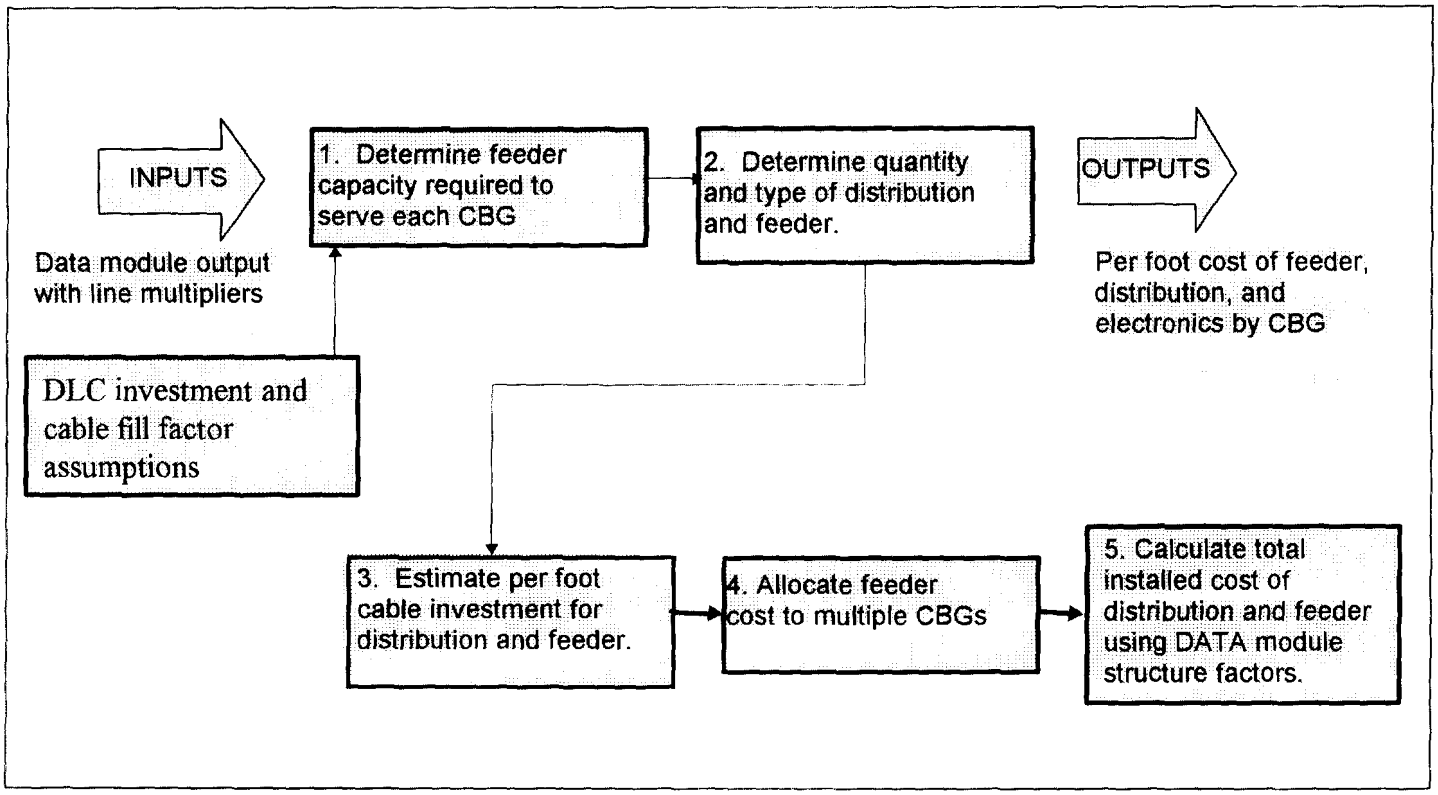
1. Overview

The Loop Module is the third of the four BCM modules. It produces the total loop facilities' investment estimate for the HM. The Loop Module employs a "bottoms-up" network design process that uses forward-looking loop plant engineering and planning practices, the best publicly available information on component prices and installation costs and least-cost cable sizing algorithms to estimate outside plant investment costs appropriate to a TSLRIC analysis. There have been no changes to the BCM algorithms in either the Data Module or the Loop Module.

However, as explained in more detail below, the Model does adjust structure multipliers to achieve more realistic costs for structure investment in low density areas than those generated by the BCM. In addition, recognizing all significant sources of access line demand in the Loop Multiplier Module results in a more realistic modeling of the overall scale of the local exchange network used by a multi-service provider than does the BCM (which sizes the network to accommodate only demand for primary residence lines).

As illustrated in Figure 1, this Module is positioned between the Data Module and the Convergence Module. The Data Module supplies the Loop Module with the calculated lengths for feeder, sub-feeder and distribution for each CBG, plus the structure factors that represent the costs of conduit, poles and other supporting investment. After the Loop Module sizes the required outside plant facilities and estimates the loop investment costs associated with each CBG, this information is forwarded to the

Figure 4 Loop Module



Convergence Module

2. Description of Inputs and Assumptions

There are two broad categories of inputs and assumptions in the Loop Module. In the first category are the loop length and structure cost inputs derived from calculations performed in the Data Module. The second category includes parameters that are used in the Loop Module, but may be adjusted by the model user. These include the cable and digital loop carrier ("DLC") equipment fill factors, DLC investments per access line and vendor discounts for copper cable, fiber cable and DLC electronics.

a) Inputs derived from the Data Module

The following outputs from the Data Module are used as inputs by the Loop Module:

"B," "A," and Distribution Distance -- These are the feeder, sub-feeder and distribution lengths calculated for each CBG